Reducing the Risks of Herbicide Resistance: Best Management Practices and Recommendations

Introduction

The following excerpt, from a special issue of the journal *Weed Science* devoted to issues concerning herbicide resistant weeds, is the Executive Summary of the manuscript "Reducing the Risks of Herbicide Resistance: Best Management Practices and Recommendations". The Executive Summary provides an account of the current best management practices and recommendations to counter the development of herbicide resistance and it was adopted by the Weed Science Society of America (WSSA) as an official position paper for the Society.

The special issue of *Weed Science* is the result of collaboration between the USDA Animal and Plant Health Inspection Service (APHIS), the federal agency responsible for regulating genetically engineered crops, and the WSSA. It is the product of more than three years of work by two groups of WSSA members. The first group was charged with writing a comprehensive manuscript containing background information on the development of herbicide resistance in weed species. This manuscript is entitled "Herbicide Resistance: Towards an Understanding of Resistance and the Impact of Herbicide Resistant Crops". The second group was charged with assessing best management practices and policies to combat the further development and spread of herbicide resistant weeds. It is the Executive Summary of this manuscript that is presented here. The special issue is intended to serve not only the Weed Science discipline but also, and perhaps more importantly, the broader community that is faced with addressing this problem.

Preprints of the articles that will appear in the special issue of *Weed Science* are freely available online in manuscript format. The preprints will be superseded by the final version, also freely available online, when it is published later this year. The following links will take you to the full manuscripts:

- "Herbicide Resistance: Towards an Understanding of Resistance and the Impact of Herbicide Resistant Crops": **http://dx.doi.org/10.1614/WS-D-11-00206.1**
- "Reducing the Risks of Herbicide Resistance: Best Management Practices and Recommendations": **http://dx.doi.org/10.1614/WS-D-11-00155.1**

Herbicide resistance in weeds has become one of the most pressing issues facing weed scientists, agricultural producers and land managers in general. This problem has received widespread attention with the development of glyphosate-resistant weeds in glyphosate-resistant (GR) crops. However, it far pre-dates glyphosate resistance. In fact, the introduction of GR crops was initially seen as a solution to weed resistance to other herbicides, such as the acetolactate synthase inhibitors, which was becoming a national, and even international, crisis in agriculture.

Federal agencies, the agrochemical industry, non-governmental organizations, farm commodity groups, and academia are engaging in an unprecedented dialog on how to preserve rare and invaluable herbicide technologies and protect soils of cropping systems in the face of rapidly expanding herbicide resistance. The interests behind this goal are quite diverse; for example, the USDA Natural Resources Conservation Service is vitally interested in preventing the abandonment of conservation tillage practices because of problems with controlling herbicide resistant weeds. The Environmental Protection Agency is responsible for pesticide stewardship and it is actively seeking proactive educational programs, rather than mandating specific weed management practices through regulatory actions, as a means to promote sound and sustainable herbicide use.

APHIS approached the WSSA in 2008 with a request to develop comprehensive background information on herbicide resistance. The purpose of this cooperative effort was to promote a common understanding of how the development of herbicide-resistant weeds was linked to herbicide use and the introduction of genetically engineered herbicide-resistant crops. In addition, APHIS wanted information on how use of herbicides in agroecosystems was causing shifts in weed populations. The

report was to outline the state of knowledge on the development, management, and impact of herbicide-resistant weeds and weed population shifts in both conventional and genetically-engineered crops. The report was also designed to be an informational tool for the general public, federal agencies, companies, and other interested entities involved in the assessment of impacts on environments and in the development of herbicide resistance management strategies. As such, the goal was to cover fundamental aspects of the biology, ecology, and physiology of weeds and herbicides as tools for weed management at a level understandable by non-weed scientists.

As this report was under development, APHIS asked the WSSA to write a second report focused on documenting the current use and success of herbicide resistance management programs in various agroecosystems, focusing on single season row crops and orchards. To accomplish this task, four questions were identified:

1. What methods are being currently used to manage the spread and development of herbicide resistance in weeds?
2. How effective are these methods and how widely are they being used?
3. Why are these methods being or not being adopted?
4. What, if anything, can be done to increase the use of integrated herbicide resistance management programs?

In evaluating and answering these questions, APHIS sought to understand both the effectiveness of individual methods and combinations of the methods. APHIS hoped that the outcome of this project would be the identification of implementable, proven, and effective management measures to avoid the spread of herbicide resistant weeds. The agency would use this information to promote effective methods for controlling or slowing the selection for herbicide resistant weeds, to address resistance management in environmental analyses under the National Environmental Policy Act, and to inform risk assessment and risk management.

EXECUTIVE SUMMARY

Herbicides are the foundation of weed control in commercial crop production systems. However, herbicide-resistant (HR) weed populations are evolving rapidly as a natural response to selection pressure imposed by modern agricultural management activities. Mitigating the evolution of herbicide resistance depends on reducing selection through diversification of weed control techniques, minimizing spread of resistance genes and genotypes via pollen or propagule dispersal, and eliminating additions of weed seed to the soil seedbank. Effective deployment of such a multi-faceted approach will require shifting from the current concept of basing weed management on single-year economic thresholds.

Herbicide resistance management programs must consider utilization of all cultural, mechanical, and herbicide options available for effective weed control in each situation and employ the following best management practices (BMPs):

1. Understand the biology of the weeds present.
2. Use a diversified approach to weed management focused on preventing weed seed production and reducing the number of weed seeds in the soil seedbank.
3. Plant into weed-free fields and then keep fields as weed free as possible.
4. Plant weed-free crop seed.
5. Scout fields routinely.
6. Use multiple herbicide mechanisms of action that are effective against the most troublesome or herbicide-resistance-prone weeds.
7. Apply the labeled herbicide rate at recommended weed sizes.
8. Emphasize cultural practices that suppress weeds by utilizing crop competitiveness.
9. Use mechanical and biological management practices where appropriate.
10. Prevent field-to-field and within-field movement of weed seed or vegetative propagules.
11. Manage weed seed at harvest and post-harvest to prevent a buildup of the weed seedbank.
12. Prevent an influx of weeds into the field by managing field borders.

The long-term economic benefits of avoiding additional costs associated with managing HR weeds are clear. Nevertheless, widespread adoption of these BMPs must overcome several real barriers. In particular, growers focus on immediate economic returns and have the belief that evolution of herbicide resistance in weeds is unavoidable and that continued availability of novel herbicide technologies will solve the problem. There is at present no single database collating

information on weed management practices employed by U.S. growers, so the extent of adoption of BMPs for HR weeds must be inferred by combining data from multiple sources. Available survey data show that while many U.S. soybean, corn, and cotton growers employ at least some BMPs, a significant proportion of growers are not practicing adequate proactive herbicide resistance management. Two key recommendations in particular must be more widely implemented:

- diversifying weed management practices and using multiple herbicide mechanisms of action (MOAs).
- Growers need to be educated about MOAs and made aware that discovery of new herbicide chemistries is rare, that the existing herbicide resource is exhaustible, and that indiscriminate herbicide use leading to rapid evolution of herbicide-resistant weeds may result in the loss of herbicide options for all.

To address the increasing urgent problem of herbicide resistance, we make the following recommendations:

1. Reduce the weed seedbank through diversified programs that minimize weed seed production.
2. Implement an herbicide mechanism of action labeling system for all herbicide products and conduct an awareness campaign.
3. Communicate that discovery of new, effective herbicide mechanisms of action is rare and that the existing herbicide resource is exhaustible.
4. Demonstrate the benefits and costs of proactive, diversified weed management systems for the mitigation of herbicide-resistant weeds.
5. Foster the development of incentives by government agencies and industry that conserve critical herbicide mechanisms of action as a means to encourage adoption of best practices.
6. Promote the application of full labeled rates at the appropriate weed and crop growth stage. When tank mixtures are employed to control the range of weeds present in a field, each product should be used at the specified label rate appropriate for the weeds present.
7. Identify and promote individual best management practices that fit specific farming segments with the greatest potential impact.
8. Engage the public and private sectors in the promotion of best management practices, including those concerning appropriate herbicide use.
9. Direct federal, state, and industry funding to research addressing the substantial knowledge gaps in BMPs for herbicide resistance and support cooperative extension services as vital agents in education for resistance management.

In some instances, short-term costs may not favor implementation of BMPs that provide insufficient immediate economic benefit, even though their adoption will delay evolution of HR weed populations over time. In such cases, consideration should be given to providing incentives and expert advice for growers to develop and implement risk-reducing weed management plans, following the precedent set by similar incentives for the conservation of soil and water resources in agriculture.

Use the following links to access the preprints of the *Weed Science* Special Issue:

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